Western Washington Hydrology Model

User's Manual

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To download the Western Washington Hydrology Model
and the electronic version of this User's Manual,
please visit our website at:

http://www.ecy.wa.gov/programs/wq/links/stormwater.html

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WESTERN WASHINGTON HYDROLOGY MODEL

User's Manual

Prepared by
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In Association with
Otak, Inc.

Purpose

Size storm water control facilities that mitigate the effects of increased runoff (peak discharge, duration, and volume) from a proposed development on a stream using a computer model that represents the following:

- a uniform method for western Washington
- a more accurate method than single event design storms
- an easy–to–use software package

The computer program is based on:

- continuous simulation hydrology (HSPF)
- actual recorded precipitation
- measured pan evaporation
- historic vegetation
- regional HSPF parameters

Parameter values can be modified for local conditions.

Computer Requirements

- Windows 9x/ME/2000 with 50 MB uncompressed hard drive space
- Internet access (only required for downloading program, not required for executing WWHM)
- Pentium 2 or faster processor (desirable)
- Color monitor (desirable)

Before Starting the Program

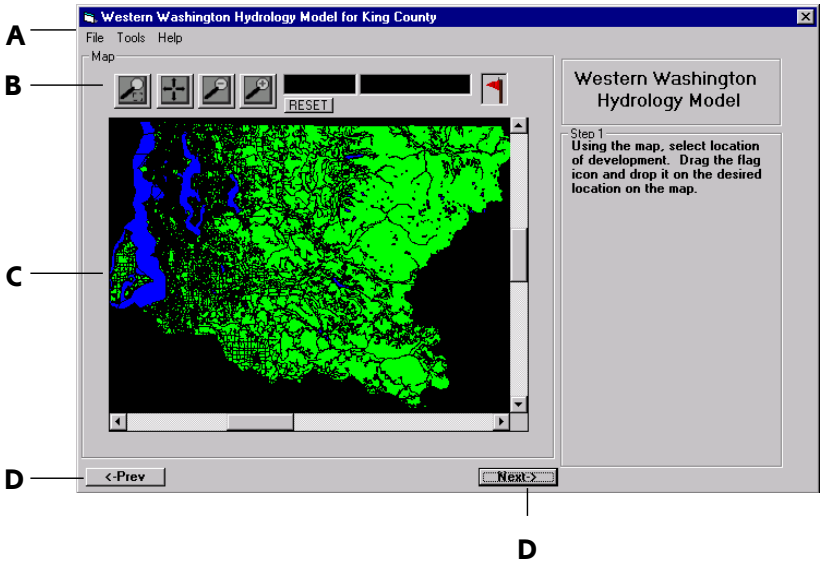
- Site location or street address
- Aerial distribution of existing site soil by category (outwash, till, wetland)
- Aerial distribution of proposed development (residences, streets/sidewalks, landscaped areas) in relation to the soil categories
- At least a first approximation for stormwater control facility (stage (ft), storage (ac-ft), discharge (cfs))

Procedure

- Assemble site characteristics
  Download the program. The program is available at ftp://www.ecy.wa.gov/ftp anon/wq/. The user needs to download the following files: setup.exe, ehm.cab, setup.lst, infoandassumptions.doc, and "name of the county"co.exe (name of the county in which the project is located, i.e., kingco.exe)
- After download is completed, user needs to run setup.exe file. This will create c:\program files\ehm folder. Now the user can access and run the model from c:\program files\ehm folder by double clicking on the ehm.exe file. However, the user must load the map file for the county of the project by double clicking on the county's name and unzipping the map information for that county. This county's map files have to be in c:\program\wwhm\map\directory.
- Step through each of the screens
- Review performance of stormwater control facility
- If facility meets requirements, stop; otherwise:
  - adjust stage–storage–discharge relationship of facility
  - review performance of facility

- WWHM is available through the Washington Department of Ecology controlled web site
- The program is downloaded to the user's personal computer and is automatically executed
- WWHM comes with default values for most input parameters
- Tool bars are available for saving or reloading project data, editing default parameter values, and finding help concerning the program
- The following pages illustrate the steps required to run the WWHM, as they would appear on screen (except for this User's Manual's explanatory graphics)

GETTING STARTED



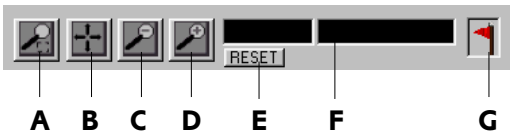
A Pull down menu

B Buttons

C Map Area

D Forward/Back Navigation buttons

THE BUTTONS



A To use **Zoom to Rectangle**, left click and draw a rectangle in the map area to view a specific location in the map.

B **Move Center**.

C The **Zoom Out** button allows the user to view a larger area at a smaller scale.

D The **Zoom In** button allows the user to view a smaller area at a larger scale.

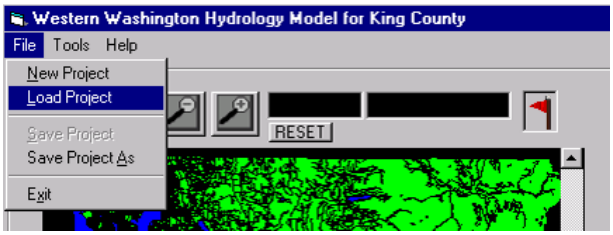
E The **Reset** button allows the user to view the full map after any zoom operations.

F The user can right-click on a street and it will be identified in these boxes. (The crosshairs must be exactly on the street line.)

G Drag the **Flag** over the map and drop in desired location. It allows the user to select a particular project site within the map.

PULL DOWN MENU

File



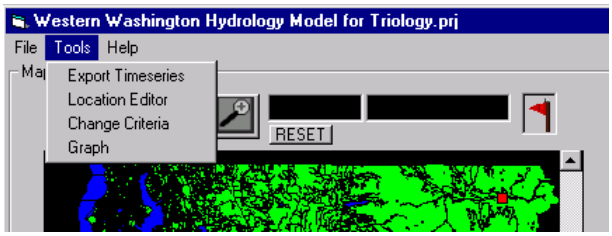
Load Project Will automatically take you to the directory c:\program files\wwhm\.

Save Project As Any new project should be saved the first time using this command.

Note: Projects may not work if saved in network folders on other computers.

File Name The program will not work if the project name includes any non alphanumeric characters. It will accept spaces in between alphanumeric characters, but not anything else.

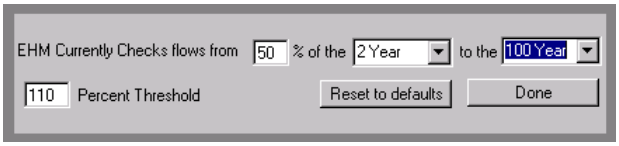
Tools

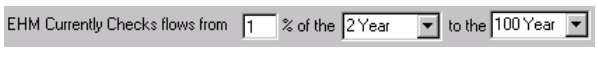


Export Timeseries Will export time series files to a specified filename under a subdirectory. This option will be available only after completing runoff and flood frequency analysis. See page 23 for further information.

Location Editor This option will be available once the project site is selected in the county selected by dragging and dropping the flag. See next page for location editor screen.

Change Criteria When this option is chosen, you get the following dialog box:





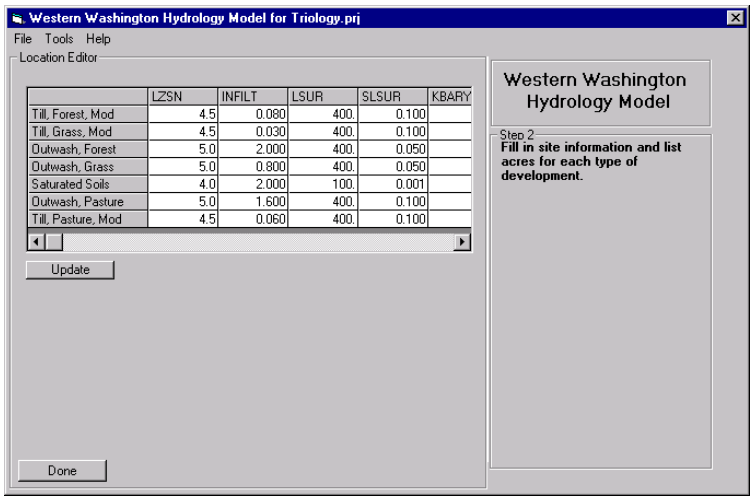
Using these three dialog boxes, any range of flow can be selected for flow duration analysis.

110 Percent Threshold = $\frac{\text{Allowable post developed flow discharge duration}}{\text{Predeveloped flow discharge duration}}$ X 100

Reset to defaults This will automatically set the values to default.

Done Once the four values are set, this will update the values.

Location Editor



LZSN	INFILT	LSUR	SLSUR	KBARY

HSPF parameters for each PERLND type which describe various hyrologic factors that influence runoff. See next page for further discussion.

Till, Forest, Mod
Till, Grass, Mod
Outwash, Forest
Outwash, Grass
Saturated Soils
Outwash, Pasture
Till, Pasture, Mod

Previous land categories represented by PERLNDs in WWHM. See next page for further discussion.

4.5	0.080	400.	0.100	
4.5	0.030	400.	0.100	
5.0	2.000	400.	0.050	
5.0	0.800	400.	0.050	
4.0	2.000	100.	0.001	
5.0	1.600	400.	0.100	
4.5	0.060	400.	0.100	

User can edit these values if better representative values are known.

Update Updates the table if values are edited.

Done Will take user to previous screen.

PERLND AND IMPLND PARAMETER VALUES.

In WWHM (and HSPF), pervious land categories are represented by PERLNDs; impervious land categories (EIA) by IMPLNDs. An example of a PERLND is a till soil covered with forest vegetation. This PERLND has a unique set of HSPF parameter values. For each PERLND there are 16 parameters that describe various hydrologic factors that influence runoff. These range from interception storage to infiltration to active groundwater evapotranspiration. Only four parameters are required to represent IMPLND.

The PERLND and IMPLND parameter values to be used in the WWHM are listed below. These values are based on regional parameter values developed by the U.S. Geological Survey for watersheds in western Washington (Dinicola, 1990) plus additional HSPF modeling work conducted by AQUA TERRA Consultants.

PERLND Parameters

	TF	TP	TL	OF	OP	OL	SF	SP	SL
Name									
LZSN	4.5	4.5	4.5	5.0	5.0	5.0	4.0	4.0	4.0
INFILT	0.08	0.06	0.03	2.0	1.6	0.80	2.0	1.8	1.0
LSUR	400	400	400	400	400	400	100	100	100
SLSUR	0.10	0.10	0.10	0.10	0.10	0.10	0.001	0.001	0.001
KVARY	0.5	0.5	0.5	0.3	0.3	0.3	0.5	0.5	0.5
AGWRC	0.996	0.996	0.996	0.996	0.996	0.996	0.996	0.996	0.996
INFEXP	2.0	2.0	2.0	2.0	2.0	2.0	10.0	10.0	10.0
INFILD	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0
BASETP	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
AGWETP	0.0	0.0	0.0	0.0	0.0	0.0	0.7	0.7	0.7
CEPSC	0.20	0.15	0.10	0.20	0.15	0.10	0.18	0.15	0.10
UZSN	0.5	0.4	0.25	0.5	0.5	0.5	3.0	3.0	3.0
NSUR	0.35	0.30	0.25	0.35	0.30	0.25	0.50	0.50	0.50
INTFW	6.0	6.0	6.0	0.0	0.0	0.0	1.0	1.0	1.0
IRC	0.5	0.5	0.5	0.7	0.7	0.7	0.7	0.7	0.7
LZETP	0.7	0.4	0.25	0.7	0.4	0.25	0.8	0.8	0.8

PERLND types:

TF / Till Forest
TP / Till Pasture
TL / Till Lawn
OF / Outwash Forest
OP / Outwash Pasture
OL / Outwash Lawn
SF / Saturated Forest
SP / Saturated Pasture
SL / Saturated Lawn

PERLND parameters:

LZSN / lower zone storage nominal (inches)
INFILT / infiltration capacity (inches/hour)
LSUR / length of surface overland flow plane (feet)
SLSUR / slope of surface overland flow plane (feet/feet)
KVARY / groundwater exponent variable ($inch^{-1}$)
AGWRC / active groundwater recession constant (day^{-1})
INFEXP / infiltration exponent
INFILD / ratio of maximum to mean infiltration
BASETP / base flow evapotranspiration (fraction)
AGWETP / active groundwater evapotranspiration (fraction)
CEPSC / interception storage (inches)
UZSN / upper zone storage nominal (inches)
NSUR / roughness of surface overland flow plane (Manning's n)
INTFW / interflow index
IRC / interflow recession constant (day^{-1})
LZETP / lower zone evapotranspiration (fraction)

A more complete description of these PERLND parameters is found in the HSPF User Manual (Bicknell et al, 1997).

PERLND parameter values for other additional soil/vegetation categories will be investigated and added to the EHM, as appropriate.

IMPLND Parameters

	EIA
Name	
LSUR	100
SLSUR	0.01
NSUR	0.10
RETSC	0.10

IMPLND parameters:

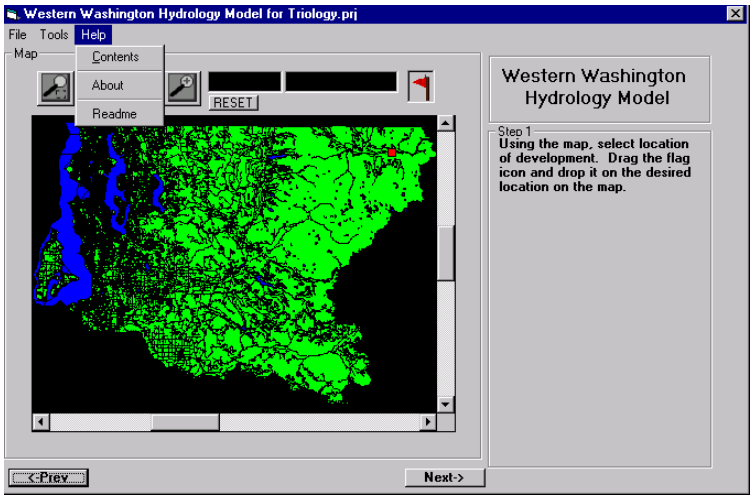
LSUR / length of surface overland flow plane (feet)
SLSUR / slope of surface overland flow plane (feet/feet)
NSUR / roughness of surface overland flow plane (Manning's n)
RETSC / retention storage (inches)

A more complete description of these IMPLND parameters is found in the HSPF User Manual (Bicknell et al, 1997).

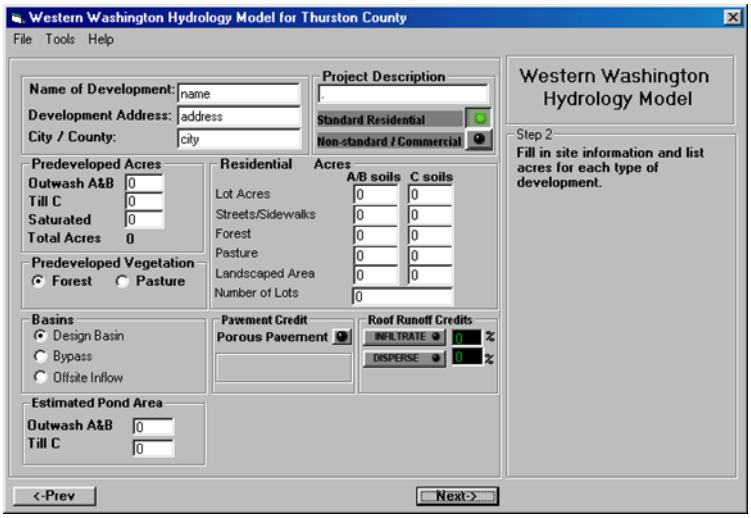
The PERLND and IMPLND parameter values will be transparent to the general user. The advanced user will have the ability to change the value of a particular parameter for that specific site. However, such changes will be recorded in the WWHM output.

Surface runoff and interflow will be computed based on the PERLND and IMPLND parameter values. Groundwater flow will not be computed, as it is assumed that there is no groundwater flow from small catchments that reach the surface to become runoff. This is consistent with King County procedures (King County, 1998).

Help

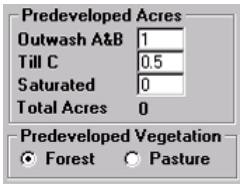

Western Washington Hydrology Model for Triology.prj
File
Tools
Help
Contents
About
Readme
Map
RESET
Western Washington Hydrology Model
Step 1
Using the map, select location of development. Drag the flag icon and drop it on the desired location on the map.
<-Prev
Next->

STANDARD RESIDENTIAL OPTION



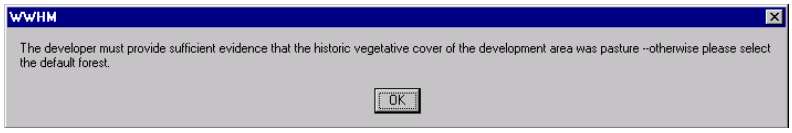
Enter project information in these fields.

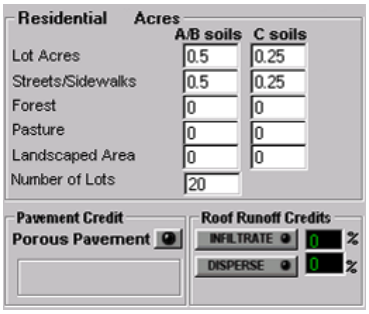
After entering project information, the user has to select **Standard Residential** or **Non–Standard Commercial** for developed conditions before entering any other values. The user has the option to choose one or the other, but not both. If there are both types of development available, the user has to analyze separately. See page 15 for further detail on development land use data.



Enter **Predeveloped Acres** appropriately.

Choose **Vegatation** type appropriately. Since pasture creates less runoff, if pasture is chosen, the user will get the following message (see page 14 for further detail on vegetation data):





Information in this dialog box represents developed conditions. See page 15 for further information on standard residential.

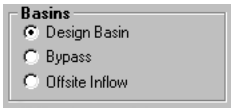
Lot Acres Enter lot acres appropriately

Note: Total acreage of A/B soils entered under predeveloped acres should match the acreage of A/B soils entered under developed conditions, and the total acreage of C soils entered under predeveloped acres should match the acreage of C soils entered under developed conditions; i.e., standard residential or non-standard/commercial, whichever the type of development. Otherwise, user will get a warning message:

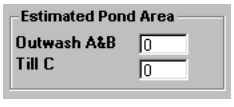
Streets/Sidewalks Input impervious area streets and sidewalks within the public row which used to be A/B soils or C soils.

Number of Lots Enter total number of lots in the standard residential area.

Pavement Credit and Roof Runoff Credits Select these options if applicable. To select, click on the buttons to make them green and then enter percentages. See page 16 for further information.



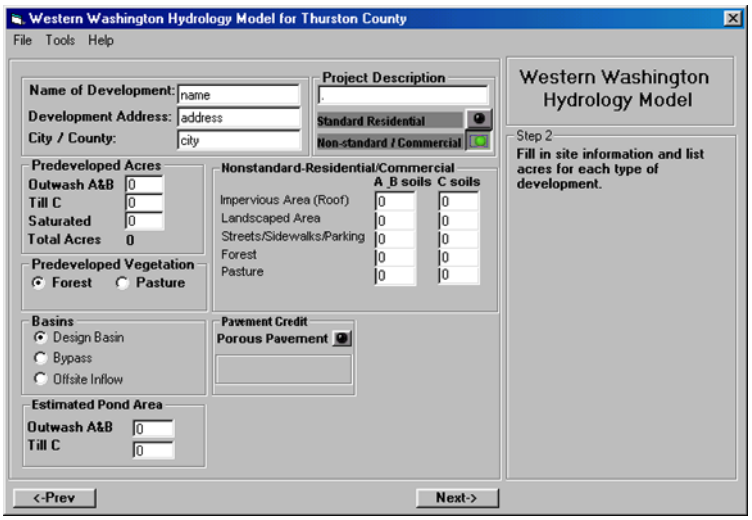
User has the option to choose one or any combination of basins. See page 17 for further information.



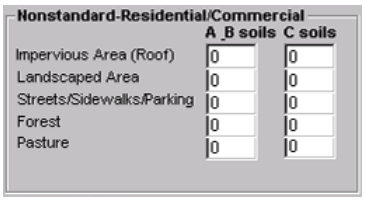
Enter an **Estimated Pond Area**. This area is considered part of the post-developed area and is modeled impervious in the "developed without facility" scenario. It is replaced by the pond in the "developed with facility" scenario.

Note: Pond area must be reentered if the user switches from standard to non-standard or vice-versa.

NON–STANDARD COMMERCIAL OPTION

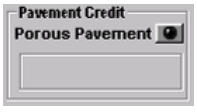


To select the **Non–Standard Commercial** option, click on the button to make it green.



Enter values appropriately. See page 17 for further information. Total Type A/B soils and Type C acreage should match under predeveloped and post-developed conditions.

User has the option to choose one or any combination of **Basins**. For each of the options selected, user has to enter the predeveloped and developed data. See page 17 for further information.



The only runoff credit availabe in non–standard/ commercial is Porous Pavement. Click there if applicable. To select this option, make the button is green. See page 16 for further information.

VEGETATION DATA

As with soil type, vegetation types greatly influence the rate and timing of the transformation of rainfall to runoff. Vegetation intercepts precipitation, increases its ability to percolate through the soil, and evaporates and transpires large volumes of water that would otherwise become runoff.

The WWHM will represent the vegetation of western Washington with three predominant vegetation categories: forest, pasture, and lawn (also known as grass).

Forest vegetation is represented by the typical second growth Douglas fir found in the Puget Sound lowlands. Forest has a large interception storage capacity. This means that a large amount of precipitation is caught in the forest canopy before reaching the ground and becoming available for runoff. Precipitation intercepted in this way is later evaporated back into the atmosphere. Forest also has the ability to transpire moisture from the soil via its root system. This leaves less water available for runoff.

Pasture vegetation is typically found in rural areas where the forest has been cleared and replaced with shrub or grass lots. Some pasture areas may be used to graze livestock. The interception storage and soil evapotranspiration capacities of pasture are less than forest. Soils may have also been compressed by mechanized equipment during clearing activities. Livestock can also compact soil. Pasture areas typically produce more runoff (particularly surface runoff and interflow) than forest areas.

Lawn vegetation is representative of the suburban vegetation found in typical residential developments. Soils have been compacted by earth moving equipment, often with a layer of top soil removed. Sod and ornamental bushes replace native vegetation. The interception storage and evapotranspiration of lawn vegetation is less than pasture. More runoff results.

Predevelopment land conditions are assumed to be forest, although the user has the option of specifying pasture if there is documented evidence that pasture vegetation was native to the predevelopment site (if this option is used, pasture predevelopment vegetation will be recorded in the WWHM output).

Forest vegetation is represented by specific HSPF parameter values that represent the forest hydrologic characteristics. As described above, the existing regional HSPF parameter values for forest are based on undisturbed second-growth Douglas fir forest found today in western Washington lowland watersheds.

Postd-evelopment vegetation will reflect the new vegetation planned for the site. The user has the choice of forest, pasture, and landscaped vegetation. Forest and pasture are only appropriate for post-development vegetation in parcels separate from standard residential or non-standard residential/commercial. The pervious land portion of the standard residential and non-standard residential/commercial is assumed to be covered with lawn vegetation, as described above.

DEVELOPMENT LAND USE DATA

Development land use data are used to represent the type of development planned for the site and are used to determine the appropriate size of the required stormwater mitigation facility.

For the purposes of the WWHM in western Washington, developed land is divided into two major categories:

1. standard residential, and
2. non-standard residential/commercial.

Standard Residential

Standard residential development makes specific assumptions about the amount of impervious area per lot and its division between driveways and rooftops. Streets and sidewalk areas are input separately. Ecology has selected a standard impervious area of 4,200 square feet per residential lot, with 1,000 square feet of that as driveway, walkway, and patio area, and the remainder as rooftop area.

Impervious, as the name implies, allows no infiltration of water into the pervious soil. All runoff is surface runoff. Impervious land typically consists of paved roads, sidewalks, driveways, and parking lots. Roofs are also hopefully impervious.

For the purposes of hydrologic modeling, only effective impervious area is categorized as impervious. Effective impervious area (EIA) is the area where there is no opportunity for surface runoff from an impervious site to infiltrate into the soil before it reaches a conveyance system (pipe, ditch, stream, etc.). An example of an EIA is a shopping center parking lot where the water runs off the pavement and directly into a catch basin where it then flows into a pipe and eventually to a stream. In contrast, some homes with impervious roofs collect the roof runoff into roof gutters and send the water down downspouts. When the water reaches the base of the downspout it can be directed either into a pipe or dumped on a splash block. Roof water dumped on a splash block then has the opportunity to spread out into the yard and soak into the soil. Such roofs are not considered to be effective impervious area. For hydrologic modeling purposes, runoff credits are given to developments that contain houses that have roof runoff systems that disperse roof runoff and allow it to drain into the soil. A runoff credit is given by assuming in the modeling that the roof area behaves hydrologically as lawn rather than EIA.

The non-effective impervious area uses the adjacent or underlying soil and vegetation properties. Vegetation often varies by the type of land use. Standard residential and non-standard residential/commercial are both assumed to have lawn as their typical pervious area vegetation.

The assumption is made in the WWHM that the EIA equals the TIA (total impervious area). This is consistent with King County's determination of EIA

acres for new developments. Where appropriate, the TIA can be reduced through the use of runoff credits (more on that below).

For standard residential developments the user will input the TIA in the public right-of-way (streets and sidewalks). In addition, the user will input the number of residential lots and the number of acres associated directly with these residential lots (public right-of-way acreages and non-residential lot acreages excluded). The number of residential lots and the associated number of acres will be used to compute the average number of residential lots per acre. This number will be used to compute the average amount of impervious area per residential lot. This value together with the number of residential lots and the public right-of-way TIA will be used by the model to calculate the total TIA for the proposed development.

Pavement or Roof Runoff Credits

Runoff credits will be given reducing runoff from standard residential lots. Runoff credits can be obtained using any or all of the three methods described below:

1. Infiltrate roof runoff
2. Disperse roof runoff
3. Use porous pavement for driveway areas

Credit is given for disconnecting the roof runoff from the development's stormwater conveyance system and infiltrating on the individual residential lots. The WWHM assumes that this infiltrated roof runoff does not contribute to the runoff flowing to the stormwater detention pond site. It disappears from the system and does not have to be mitigated.

Credit is also given for disconnecting the roof runoff from the development's stormwater conveyance system and dispersing it on the surface of individual lots. This runoff is assumed to be the equivalent of runoff from lawn vegetation.

The third option for runoff credit is the use of porous pavement for private driveway areas. Specific HSPF parameters for porous pavement have not been developed for the WWHM. Ecology has made the assumption that porous pavement runoff is equivalent to the conversion of 147 square feet (4200*0.035) of impervious area to lawn vegetation. This assumption is used in the WWHM calculations.

Forest and pasture vegetation areas are only appropriate for separate undeveloped parcels dedicated as open space, wetland buffer, or park within the total area of the standard residential development.

Non–Standard Residential/ Commercial

Non-standard residential/commercial development includes residential developments for which the standard residential development assumptions are inappropriate, plus commercial, industrial, schools, roads, multi-family residential (apartments, condos), and other non-single family residential developments. For this type of development the user will input the roof area, landscaped area, street/sidewalk/parking areas, and any appropriate non-developed forest and pasture areas. Developed runoff will be calculated based on these categories and their areas. The only explicit runoff credit available to the user is porous pavement for streets, sidewalks, and parking lots. It is specified as a percent of the total street/sidewalk/parking impervious area. The user can also implicitly obtain other runoff credits by decreasing roof area and street/sidewalk/parking areas. This will decrease surface runoff.

Forest and pasture vegetation areas are only appropriate for separate undeveloped parcels dedicated as open space, wetland buffer, or park within the total area of the development.

Basins

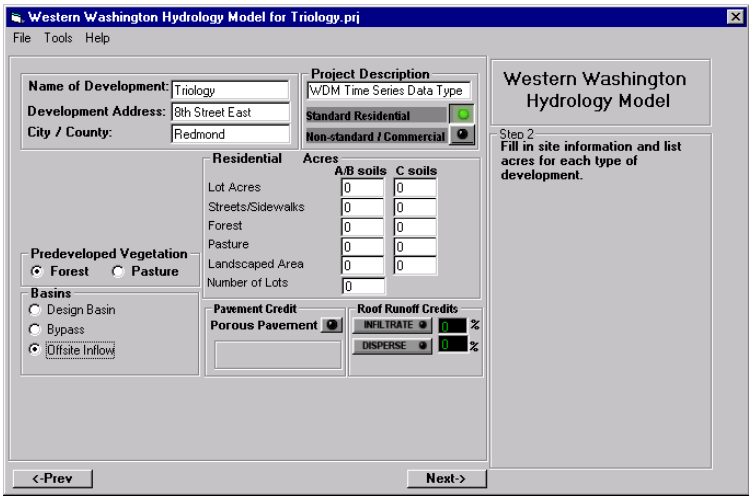
The WWHM allows the flexibility of routing a portion of the development area around a stormwater detention facility and/or having offsite inflow enter the development area. Three options are available to the user:

1. Design Basin: usual development situation with no offsite inflow and no flow bypass.
2. Bypass: a portion of the development does not drain to a stormwater detention facility.
3. Offsite Inflow: an upslope area outside the development drains to the stormwater detention facility in the development.

For each of these options the user inputs the number of acres in the different categories for the predevelopment and post-development land use. When Offsite Inflow option is chosen, the user will enter the areas under developed conditions only since this offsite area is out of the development. See next page. For each type of basin being selected, user has to choose Standard Residential or Non–Standard Commercial before entering any values in the developed areas. The WWHM computes the runoff from each separately and adds them together, as appropriate, to check to see if the stormwater standards have been satisfied.

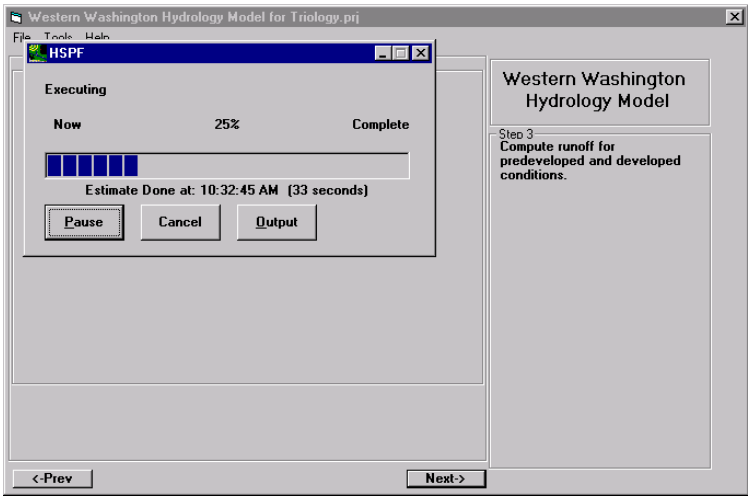
With all of the above information provided by the user, the WWHM computes the corresponding number of acres of pervious and impervious land and assigns these acres to specific PERLNDs and IMPLNDs (HSPF-speak for pervious land categories and impervious land categories) for use by the model in computing post-development runoff.

OFFSITE INFLOW SELECTED



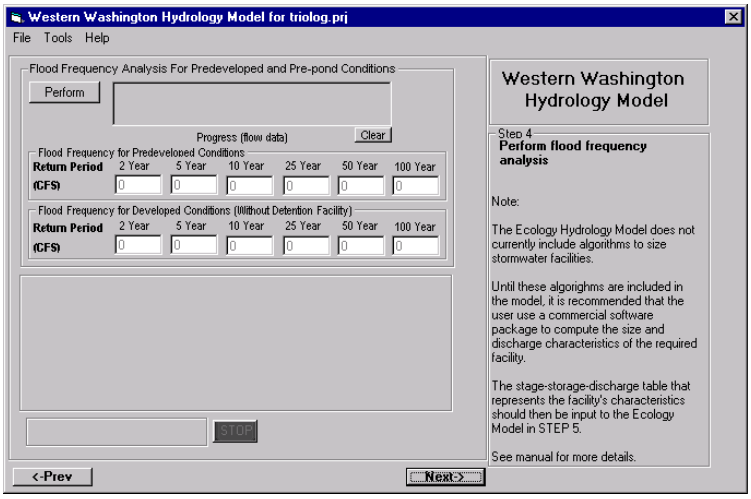
- Entering predeveloped areas will not be an option when Offsite Inflow is chosen.
- User enters the areas values under the Developed Conditions only.

When the **Next** button is pressed after entering all the values, click Yes to **Compute Runoff**.



Program now computes runoff for predeveloped and developed conditions. Once this dialog box disappears, click on **Next** to go to the next step.

PERFORMING ANALYSIS



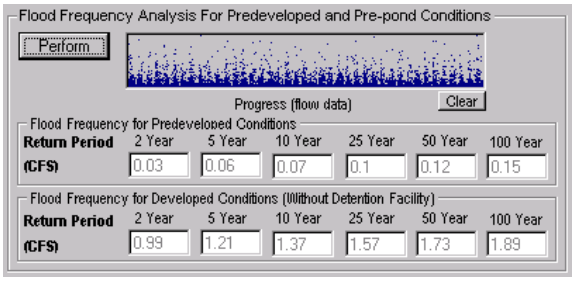
Perform Click here to compute Flood Frequency and Flood Duration values. When this option is chosen, user will see three graphs progressing in the box next to it.

Black Flood frequency values for predeveloped conditions.

Red Flood duration values for predeveloped.

Blue Flood frequency values for post- development without facility.

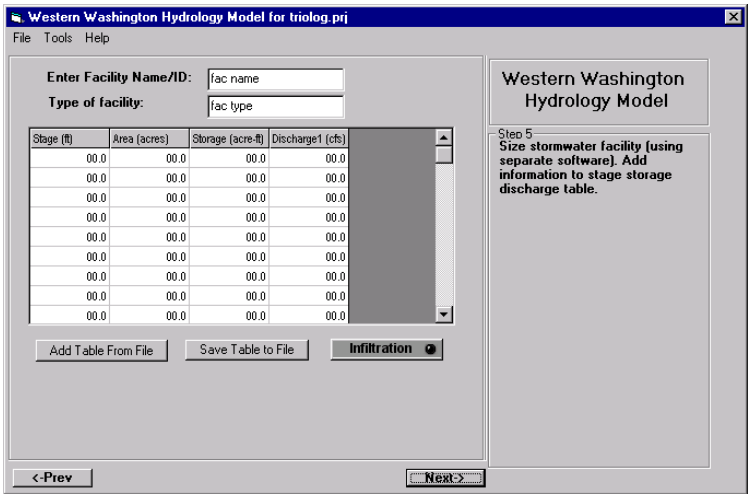
Flood frequency is computed using USGS standard Log-Pearson Type III procedures rather than assuming a preselected year for a specified flood event. The flood frequency computations include a regional skew coefficient. The regional skew coefficient is not input by the user, but is determined from Plate I of Bulletin 17B (the USGS refers to the regional skew coefficient as the "generalized skew coefficient") for Western Washington. Plate I shows the coefficient is 0.0 for areas east of the Olympic Mountains and 0.2 for areas west. These values have been included in the dataset.



Once Flood Frequency and Flood Duration analyses are done, corresponding values show up. Note: After this step, if user edits any values in Location Editor (see page 6), user must compute runoff again by clicking Previous button. The program will not update the analysis by itself.

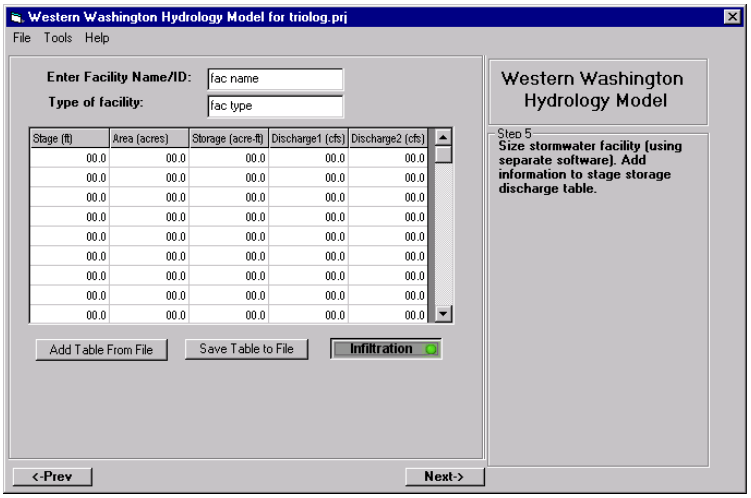
Next Click to go to the next step.

INFILTRATION OPTION

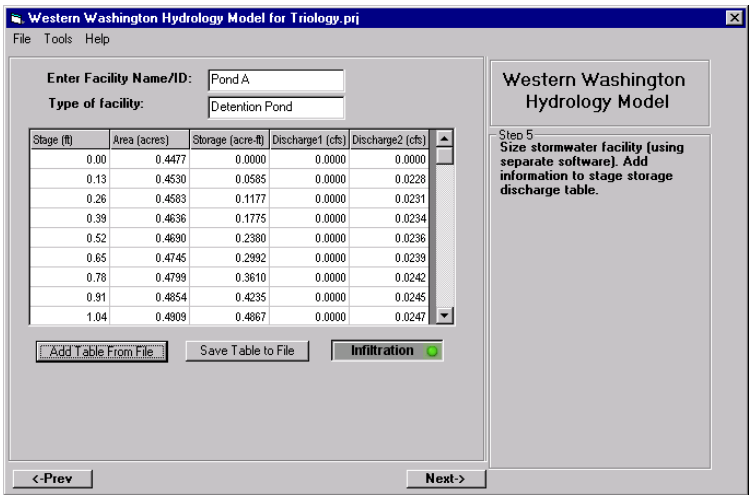


Infiltration If the facility has infiltration capacity, choose this option by clicking and making the button green. If not, click on Add Table From File. Enter Facility Name and Type of Facility. (The file can be a *.csv, tab delimited, or a text file with the numbers separated by spaces.)

Note: When manually entering numbers in this table, decimal numbers less than one must be preceded by a zero.



Screen with **Infiltration** option chosen.



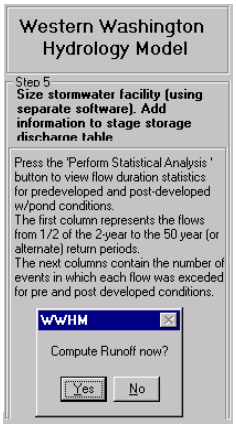
Enter Facility Name and **Type of Facility** information.

Add Table From File File should be a CSV (Comma delimited)(*.csv) one. The file should have five columns if Infiltration option is chosen, otherwise it should have four columns.

User should note the following:

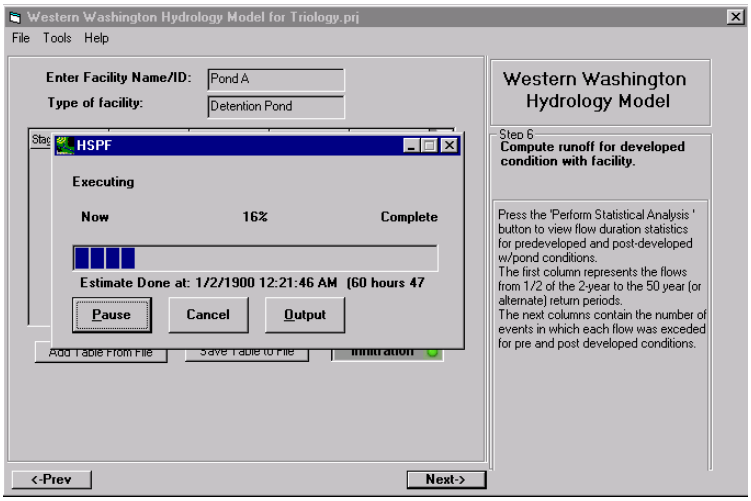
- When importing or entering values, values should be consistent with the units in the heading.
- The first row of values must be zero.
- **Stage** must increase from one row to the next.
- **Storage** should increase from one row to the next.
- Maximum number of total values is 500 (5 x 100 if infiltration option is chosen) or 400 (4 x 100 if infiltration option is not chosen).
- Maximum number of rows is 99.

Next Once finished entering all the values, click here to go to the next step.

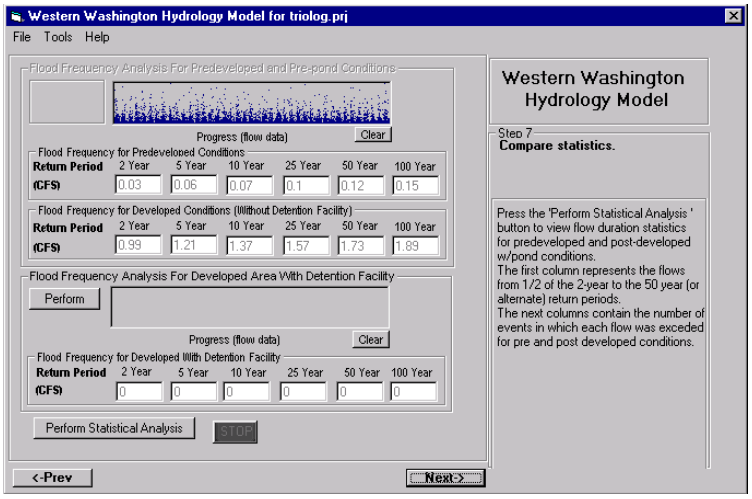


Click **Yes** to compute analysis with pond.

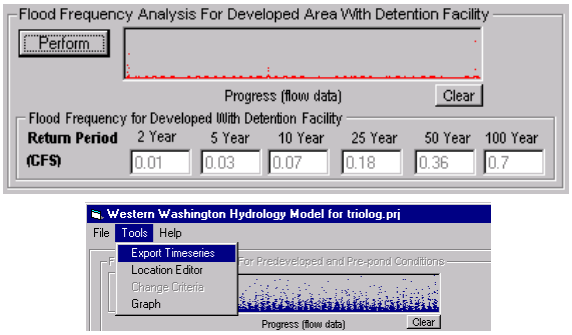
COMPUTING RUNOFF



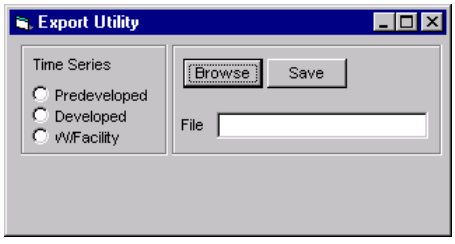
The program now computes runoff for developed conditions with facility. Once completed, click on **Next** to go to Step 7.



Perform Click to see computer peaks with detention facility:

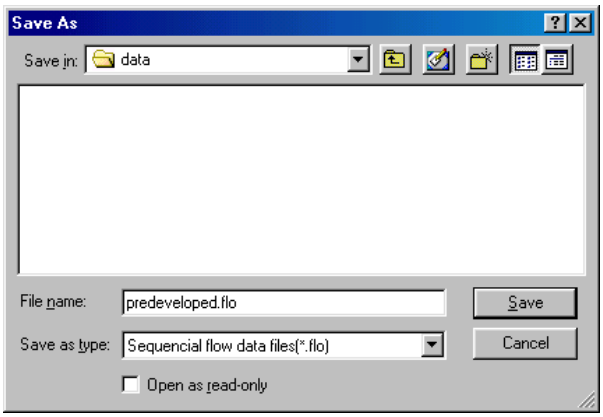


Once the Flood Frequency Analysis is done for Predevelopment, Post-development and Post-development with Detention Facility, user can **Export Timeseries** to a specified location:



Time Series User has to choose one at a time. Follow through next three screen shots.

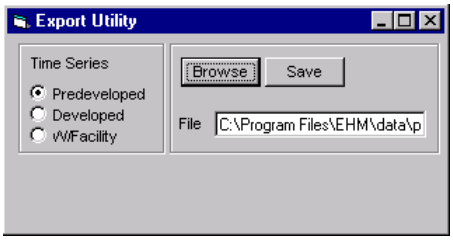
Browse Click here to give a file name. The program will take the user automatically to c:\program files\wwhm\data directory. See next screen.



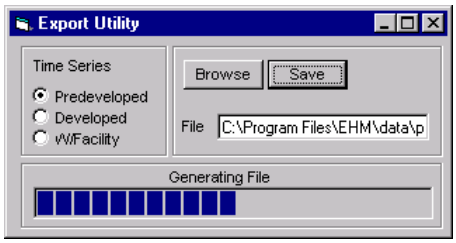
File Name Enter file name.

Save as type Data is exported to a sequential file for use with HSPF.

Save Click Save when done.



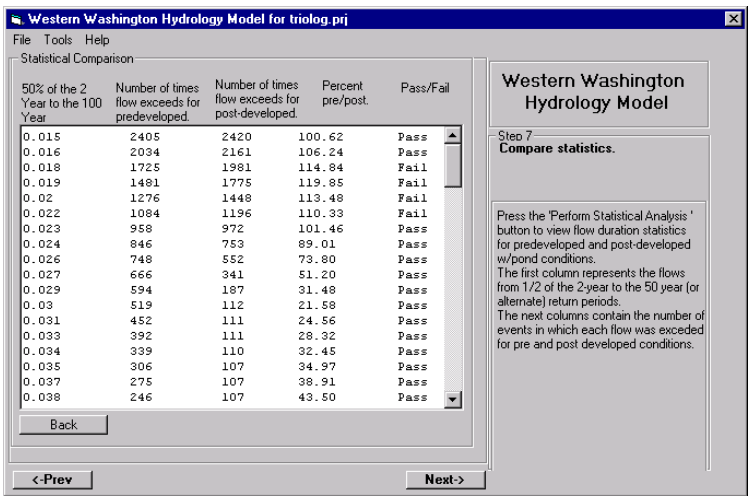
To actually generate the file in the format selected and to save, user must click here. See next screen.



Program is generating and saving.

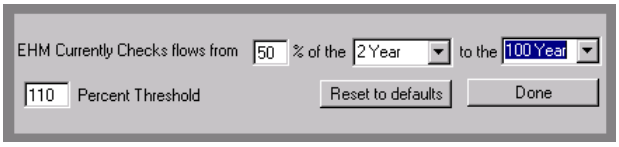
Perform Statistical Analysis Click here to perform Statistical Analysis in Step 7 (page 23). See next screen. Anytime if the user edits values under change criteria (see page 5), the user has to perform statistical analysis again by pressing this button in Step 7 (see page 23). The program will not update the results automatically.

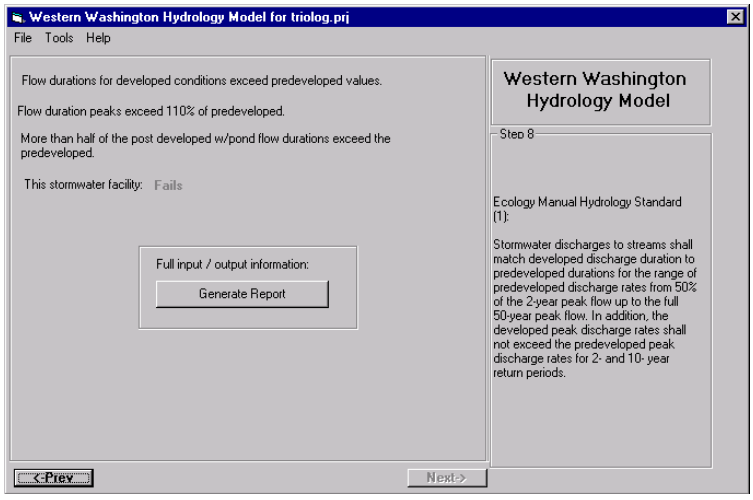
The program rates the detention facility as Pass if none of the values in Column 5 fail and if no more than 50% of the values in column 4 exceed 100%. See next screen.



The program computes individual **Pass/Fail Rate** based on whether the value in column 4 exceeds **Percent Threshold**. In this case, it is 110%.

The program computes **Flow Duration** values for 98 incremental flow values between the floods.

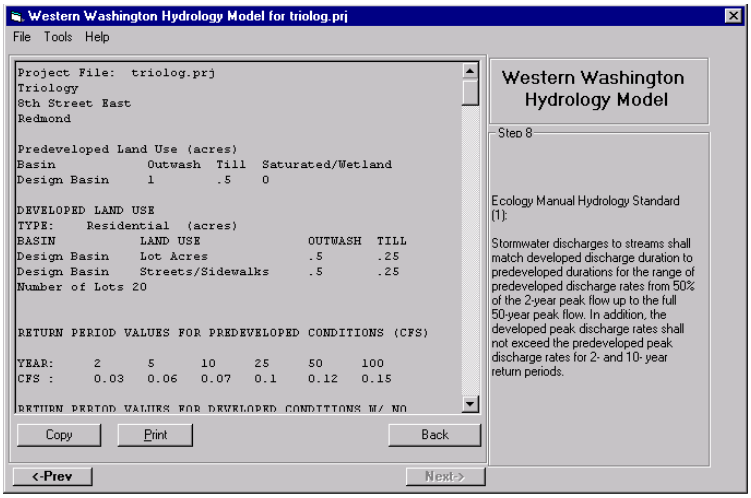




The program rated the facility Pass or Fail.

User must save project before clicking on **Generate Report**.

See next screen.



After highlighting the report, user can click on **Copy** to copy text to a different program and save file there. See following pages for report.

Click on **Print** to print the file.

REPORT

Project File: triology.prj
Triology
8th Street East
Redmond

Predeveloped Land Use (acres)

Basin	Outwash	Till	Saturated/Wetland
Design Basin	1	.5	0

DEVELOPED LAND USE
TYPE: Residential (acres)

BASIN	LAND USE	OUTWASH	TILL
Design Basin	Lot Acres	.5	.25
Design Basin	Streets/Sidewalks	.5	.25

Number of Lots 20

RETURN PERIOD VALUES FOR PREDEVELOPED CONDITIONS (CFS)

YEAR:	2	5	10	25	50	100
CFS :	0.03	0.06	0.07	0.1	0.12	0.15

RETURN PERIOD VALUES FOR DEVELOPED CONDITIONS W/ NO DETENTION FACILITY(CFS)

YEAR:	2	5	10	25	50	100
CFS :	0.99	1.21	1.37	1.57	1.73	1.89

RETURN PERIOD VALUES FOR POST-DEVELOPED CONDITIONS W/POND (CFS)

YEAR:	2	5	10	25	50	100
CFS :	0.01	0.03	0.07	0.18	0.36	0.7

DETENTION FACILITY INFORMATION:

NAME OF FACILITY: Pond A
TYPE OF FACILITY: Detention Pond

Depth (ft)	Area (acres)	Volume (acre-ft)	Outflow1 (cfs)	
0.00	0.4477	0.0000	0.0000	0.0000
0.13	0.4530	0.0585	0.0000	0.0228
0.26	0.4583	0.1177	0.0000	0.0231
0.39	0.4636	0.1775	0.0000	0.0234
0.52	0.4690	0.2380	0.0000	0.0236
0.65	0.4745	0.2992	0.0000	0.0239
0.78	0.4799	0.3610	0.0000	0.0242
0.91	0.4854	0.4235	0.0000	0.0245
1.04	0.4909	0.4867	0.0000	0.0247
1.17	0.4964	0.5506	0.0000	0.0250
1.30	0.5020	0.6152	0.0000	0.0253
1.43	0.5076	0.6804	0.0000	0.0256
1.56	0.5132	0.7463	0.0011	0.0259
1.69	0.5189	0.8129	0.0019	0.0262
1.82	0.5245	0.8803	0.0025	0.0264
1.95	0.5302	0.9483	0.0029	0.0267
2.08	0.5360	1.0170	0.0033	0.0270
2.21	0.5418	1.0865	0.0037	0.0273
2.34	0.5476	1.1566	0.0040	0.0276

2.47	0.5534	1.2275	0.0043	0.0279
2.60	0.5592	1.2991	0.0046	0.0282
2.73	0.5651	1.3714	0.0048	0.0285
2.86	0.5711	1.4445	0.0051	0.0288
2.99	0.5770	1.5183	0.0053	0.0291
3.12	0.5830	1.5928	0.0055	0.0294
3.25	0.5890	1.6680	0.0057	0.0297
3.38	0.5950	1.7440	0.0060	0.0300
3.51	0.6011	1.8208	0.0062	0.0303
3.64	0.6072	1.8983	0.0064	0.0306
3.77	0.6133	1.9765	0.0065	0.0309
3.90	0.6195	2.0555	0.0067	0.0312
4.03	0.6256	2.1353	0.0081	0.0315
4.16	0.6319	2.2158	0.0098	0.0319
4.29	0.6381	2.2971	0.0109	0.0322
4.42	0.6444	2.3792	0.0118	0.0325
4.55	0.6507	2.4620	0.0126	0.0328
4.68	0.6570	2.5456	0.0133	0.0331
4.81	0.6634	2.6300	0.0140	0.0334
4.94	0.6697	2.7152	0.0146	0.0338
5.07	0.6762	2.8012	0.0178	0.0341
5.20	0.6826	2.8880	0.0202	0.0344
5.33	0.6891	2.9756	0.0219	0.0347
5.46	0.6956	3.0639	0.0235	0.0351
5.59	0.7021	3.1531	0.0248	0.0354
5.72	0.7087	3.2431	0.0261	0.0357
5.85	0.7153	3.3339	0.6432	0.0361
5.98	0.7219	3.4255	2.1769	0.0364
6.11	0.7286	3.5179	4.2367	0.0367
6.24	0.7353	3.6112	6.7114	0.0371
6.37	0.7420	3.7053	9.5404	0.0374
6.50	0.7487	3.8002	12.6837	0.0377
6.63	0.7555	3.8959	16.1127	0.0381
6.76	0.7623	3.9925	19.8051	0.0384
6.89	0.7691	4.0899	23.7434	0.0388
7.02	0.7760	4.1882	27.9131	0.0391
7.15	0.7829	4.2873	32.3020	0.0395
7.28	0.7898	4.3872	36.8997	0.0398
7.41	0.7967	4.4881	41.6970	0.0402
7.54	0.8037	4.5897	46.6860	0.0405
7.67	0.8107	4.6923	51.8596	0.0409
7.80	0.8178	4.7957	57.2114	0.0412
7.93	0.8248	4.9000	62.7356	0.0416
8.06	0.8319	5.0051	68.4271	0.0419
8.19	0.8390	5.1111	74.2811	0.0423
8.32	0.8462	5.2180	80.2931	0.0427
8.45	0.8534	5.3258	86.4591	0.0430
8.58	0.8606	5.4345	92.7754	0.0434
8.71	0.8678	5.5441	99.2384	0.0438
8.84	0.8751	5.6545	105.8450	0.0441
8.97	0.8824	5.7659	112.5920	0.0445
9.10	0.8897	5.8782	119.4766	0.0449
9.23	0.8971	5.9913	126.4960	0.0452
9.36	0.9045	6.1054	133.6479	0.0456
9.49	0.9119	6.2204	140.9297	0.0460
9.62	0.9194	6.3363	148.3391	0.0464
9.75	0.9268	6.4532	155.8740	0.0467
9.88	0.9344	6.5709	163.5324	0.0471
10.01	0.9419	6.6896	171.3123	0.0475
10.14	0.9495	6.8092	179.2118	0.0479

10.27	0.9571	6.9298	187.2291	0.0483
10.40	0.9647	7.0513	195.3625	0.0486
10.53	0.9723	7.1737	203.6104	0.0490
10.66	0.9800	7.2971	211.9713	0.0494
10.79	0.9877	7.4214	220.4435	0.0498
10.92	0.9955	7.5467	229.0258	0.0502
11.05	1.0033	7.6729	237.7166	0.0506
11.18	1.0111	7.8001	246.5146	0.0510
11.31	1.0189	7.9283	255.4186	0.0514
11.44	1.0267	8.0574	264.4273	0.0518
11.57	1.0346	8.1875	273.5395	0.0522
11.70	1.0426	8.3186	282.7541	0.0526
11.83	1.0505	8.4506	292.0698	0.0530
11.96	1.0585	8.5837	301.4857	0.0534
12.09	1.0665	8.7177	311.0006	0.0538
12.22	1.0745	8.8527	320.6136	0.0542
12.35	1.0826	8.9887	330.3237	0.0546
12.48	1.0907	9.1257	340.1298	0.0550
12.61	1.0988	9.2637	350.0311	0.0554
12.74	1.1070	9.4027	360.0267	0.0558

STATISTICAL ANALYSIS FOR PREDEVELOPED
AND DEVELOPED WITH FACILITY

Analysis from 50% of the 2 Year to the 100 Year.

Flows (CFS)	# of times flow exceeds predeveloped	# of times flow exceeds developed	% developed compared to predeveloped	Pass/Fail
.02	2405.	2420.	100.62	Pass
.02	2034.	2161.	106.24	Pass
.02	1725.	1981.	114.84	Fail
.02	1481.	1775.	119.85	Fail
.02	1276.	1448.	113.48	Fail
.02	1084.	1196.	110.33	Fail
.02	958.	972.	101.46	Pass
.02	846.	753.	89.01	Pass
.03	748.	552.	73.8	Pass
.03	666.	341.	51.2	Pass
.03	594.	187.	31.48	Pass
.03	519.	112.	21.58	Pass
.03	452.	111.	24.56	Pass
.03	392.	111.	28.32	Pass
.03	339.	110.	32.45	Pass
.04	306.	107.	34.97	Pass
.04	275.	107.	38.91	Pass
.04	246.	107.	43.5	Pass
.04	226.	106.	46.9	Pass
.04	199.	106.	53.27	Pass
.04	178.	106.	59.55	Pass
.04	162.	106.	65.43	Pass
.05	137.	106.	77.37	Pass
.05	123.	104.	84.55	Pass
.05	111.	104.	93.69	Pass
.05	98.	103.	105.1	Pass
.05	88.	101.	114.77	Fail

.05	78.	101.	129.49	Fail
.05	73.	100.	136.99	Fail
.05	62.	100.	161.29	Fail
.06	54.	98.	181.48	Fail
.06	52.	97.	186.54	Fail
.06	48.	97.	202.08	Fail
.06	45.	96.	213.33	Fail
.06	43.	96.	223.26	Fail
.06	41.	96.	234.15	Fail
.06	39.	96.	246.15	Fail
.07	34.	96.	282.35	Fail
.07	31.	94.	303.23	Fail
.07	29.	94.	324.14	Fail
.07	27.	94.	348.15	Fail
.07	27.	94.	348.15	Fail
.07	26.	94.	361.54	Fail
.07	23.	94.	408.7	Fail
.07	23.	94.	408.7	Fail
.08	22.	94.	427.27	Fail
.08	22.	94.	427.27	Fail
.08	21.	93.	442.86	Fail
.08	19.	91.	478.95	Fail
.08	17.	91.	535.29	Fail
.08	17.	91.	535.29	Fail
.08	15.	91.	606.67	Fail
.09	15.	91.	606.67	Fail
.09	14.	91.	650.	Fail
.09	14.	91.	650.	Fail
.09	14.	90.	642.86	Fail
.09	13.	89.	684.62	Fail
.09	12.	89.	741.67	Fail
.09	12.	89.	741.67	Fail
.1	12.	88.	733.33	Fail
.1	11.	87.	790.91	Fail
.1	10.	87.	870.	Fail
.1	10.	85.	850.	Fail
.1	10.	84.	840.	Fail
.1	9.	83.	922.22	Fail
.1	9.	83.	922.22	Fail
.1	9.	83.	922.22	Fail
.11	9.	83.	922.22	Fail
.11	9.	83.	922.22	Fail
.11	9.	83.	922.22	Fail
.11	9.	83.	922.22	Fail
.11	9.	83.	922.22	Fail
.11	9.	83.	922.22	Fail
.11	8.	83.	1037.5	Fail
.12	8.	83.	1037.5	Fail
.12	8.	83.	1037.5	Fail
.12	7.	80.	1142.86	Fail
.12	6.	80.	1333.33	Fail
.12	5.	80.	1600.	Fail
.12	5.	80.	1600.	Fail
.12	5.	80.	1600.	Fail
.12	5.	80.	1600.	Fail
.13	5.	80.	1600.	Fail
.13	5.	79.	1580.	Fail
.13	4.	79.	1975.	Fail
.13	4.	79.	1975.	Fail
.13	4.	79.	1975.	Fail

.13	4.	79.	1975.	Fail
.13	4.	79.	1975.	Fail
.14	4.	79.	1975.	Fail
.14	4.	79.	1975.	Fail
.14	3.	78.	2600.	Fail
.14	3.	78.	2600.	Fail
.14	2.	77.	3850.	Fail
.14	2.	77.	3850.	Fail
.14	1.	75.	7500.	Fail
.15	1.	75.	7500.	Fail
.15	1.	75.	7500.	Fail
.15	1.	75.	7500.	Fail
.15	1.	74.	7400.	Fail

Flow durations for developed conditions exceed predeveloped values.

Flow duration peaks exceed 110% of predeveloped.

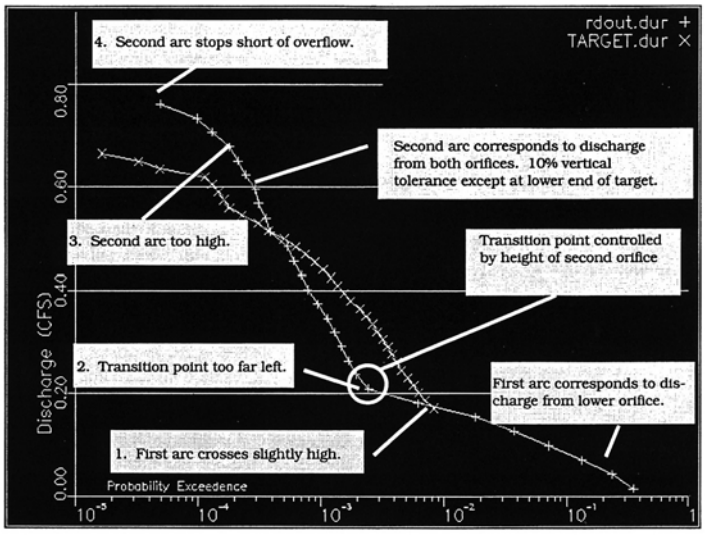
Analyzing WWHM Output

- In most instances, you will be required to meet a flow duration standard
- Desirable to view output as a graph of discharge versus probability of exceedence(inverse of return period)

Analyzing Flow Duration Curves

- Analyze curve from bottom to top, and adjust orifices from bottom to top
- Bottom arc corresponds with the discharge from the bottom orifice
  - reducing the bottom orifice discharge lowers and shortens the bottom arc
  - increasing the bottom orifice raises and lengthens the bottom arc
- Inflection points in the outflow curve occur when additional components (orifices, notches, overflows) become engaged
  - lowering the upper orifice moves the breakpoint right on the lower arc
  - raising the upper orifice moves the breakpoint left of the lower arc
- Upper arc represents the combined discharge of both orifices. Adjustments are made to the second orifice as described above for the bottom orifice
- Increasing facility volume (via bottom length, width area) moves the entire curve down and to the left. This is done to control riser overflow conditions.
- Decreasing facility volume (via bottom length, width, area) moves the entire curve up and to the right. This is done to ensure that the outflow duration curve extends up to riser overflow.
- The upper tail of the outflow curve will usually not extend all the way to the riser overflow line. If the riser overflow line does not appear on the graph, reduce the facility volume until it appears.

Flow Duration Standard (example)



Observation

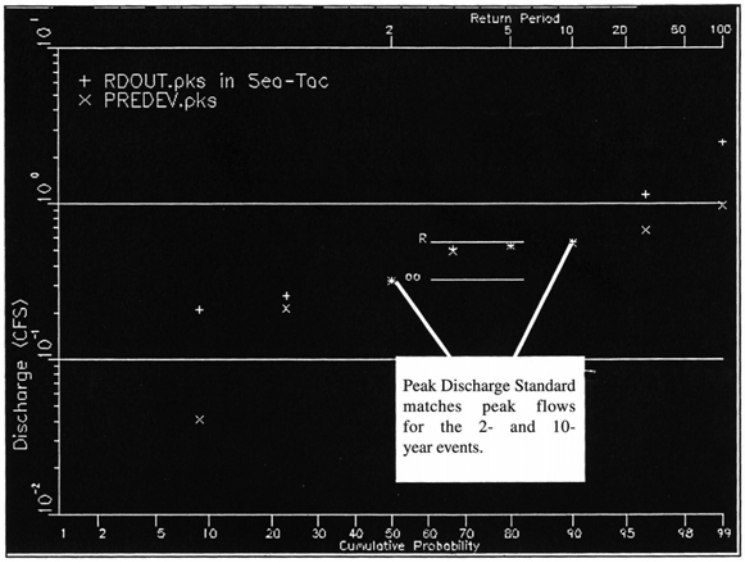
1. First arc crosses too high
2. Transition point too far left
3. Second arc too high
4. Second arc stops short of overflow

Refinement

1. Reduce bottom orifice diameter
2. Lower second orifice
3. Reduce second orifice diameter
4. Reduce volume of facility if after the above refinements, the second arc still stops short of the overflow

When required to meet discharge standard, look at the results and adjust orifice elevation and/or size in a manner similar to that described for the duration standard output evaluation.

Peak Discharge Standard (example)



Refinements should be made in small increments. Refine one structure at a time, until you are familiar with the process and the results that you can expect with any one refinement.

Start adjustments by refining the structure controlling the low flow discharge and duration. Proceed to the next higher structure after achieving satisfactory results with the lower structure.

GRAPHING CAPABILITY

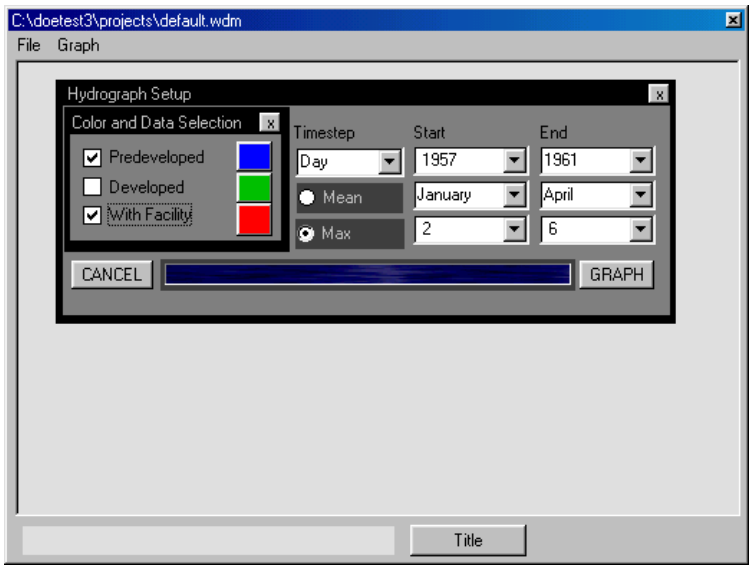
The following is a description of the WWHM graphing capabilities, including screenshots.

The flow frequency and duration analysis must be performed in the WWHM before the graph will function.

From the Graph Menu, choose from three types of graphs:

- Hydrograph
- Flow Frequency
- Duration Analysis

Hydrograph:

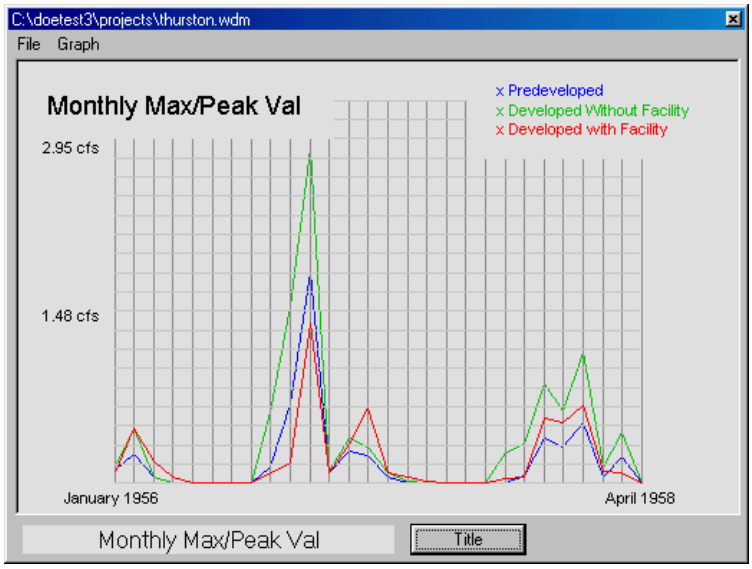


In the Hydrograph Setup, the user must choose which dataset(s) to graph, the interval and the beginning and end dates to graph.

Also the user must specify whether mean/average or max/peak values are used.

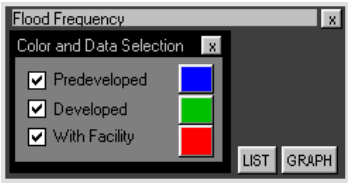
Example If the graph is of monthly values for a number of years, each month can be represented by either the maximum flow value for that month or the mean/average flow value during that month.

When the selections have been made, click GRAPH. The program will take some time preparing the graph data.



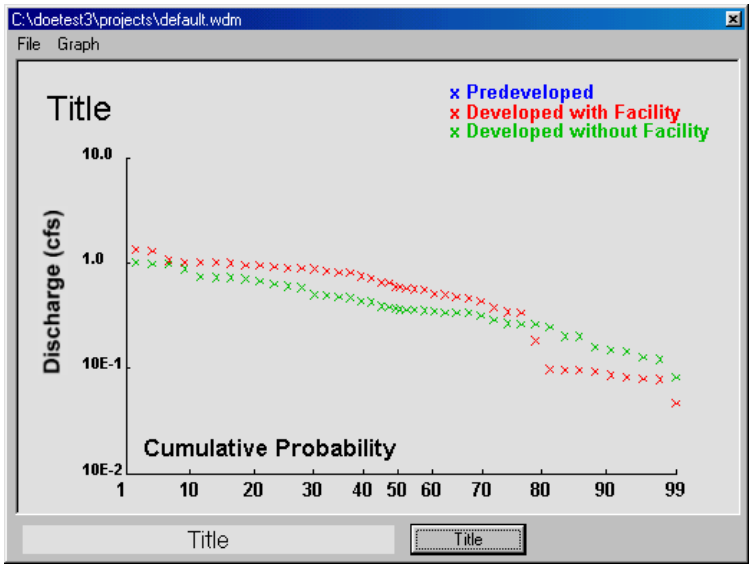
Monthly peak values for January 1, 1956 to April 1, 1958.

Flow Frequency:



The user must specify which dataset(s) are to be plotted and click GRAPH.

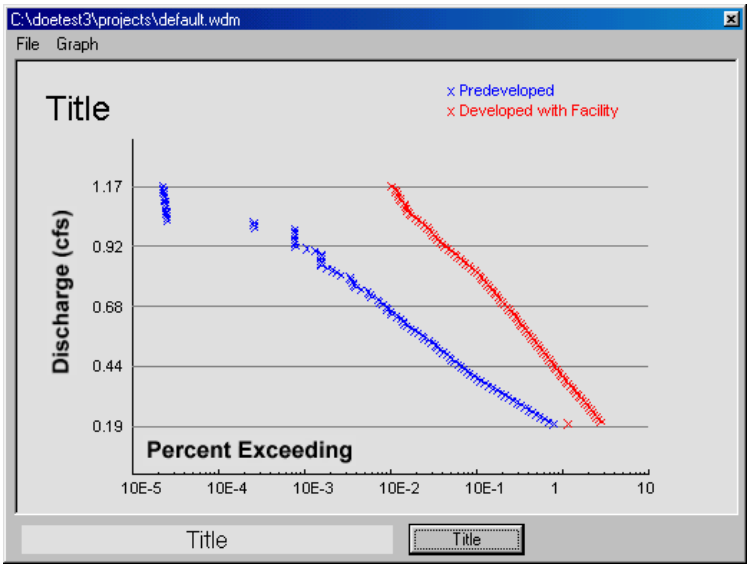
Note: the user can choose different colors to represent datasets by clicking on their respective color boxes.



Discharge is represented in a Log scale, while cumulative probability is shown in a scale expanding from the center.

Duration Analysis

The Duration analysis uses datasets for pre developed and developed with facility only.



Discharge is represented as ½ the 2 year return value* to the 50 year return value.*

100 points represent the percentage of flow values that exceed 100 intervals between the ½ 2 year and 50 year values.

From the File Menu, the user can print the graph or export it to a Bitmap (bmp), Windows Metafile (emf) or a Jpeg (jpg) file.

*These values can be adjusted in the WWHM.